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Landsat 8 OLI and Sentinel 2 Data Interoperability: Looking from the Calibration Perspective

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Overview

- **Introduction**
  – Landsat 8 and the Sentinel 2 missions
- **Calibration of Landsat and Sentinel 2**
- **Landsat/Sentinel Data Interoperability**
  – Calibration Site Perspective
- **Conclusions**

Landsat 8 Overview

- Launched Feb 11, 2013
- 16 day repeat coverage (8 day with Landsat 7)
- 3% Reflectance-based absolute radiometric calibration
- Equatorial crossing time: 10am ± 15 min
- Field of view: 15^{o}, 185km

Band	Description	Wavelength (micrometers)	Resolution (meters)
1*	Violet-Deep Blue	0.43 – 0.45	30
2*	Blue	0.45 – 0.51	30
3*	Green	0.53 – 0.59	30
4*	Red	0.64 – 0.67	30
5	Near Infrared	0.85 – 0.88	30
6	Shortwave Infrared	1.57 – 1.65	30
7	Shortwave Infrared	2.11 – 2.29	30
8*	Panchromatic	0.50 – 0.68	15
9	Cirrus clouds	1.36 – 1.38	30
10**	Thermal infrared	10.62 – 11.19	30
11**	Thermal infrared	11.50 – 12.51	30

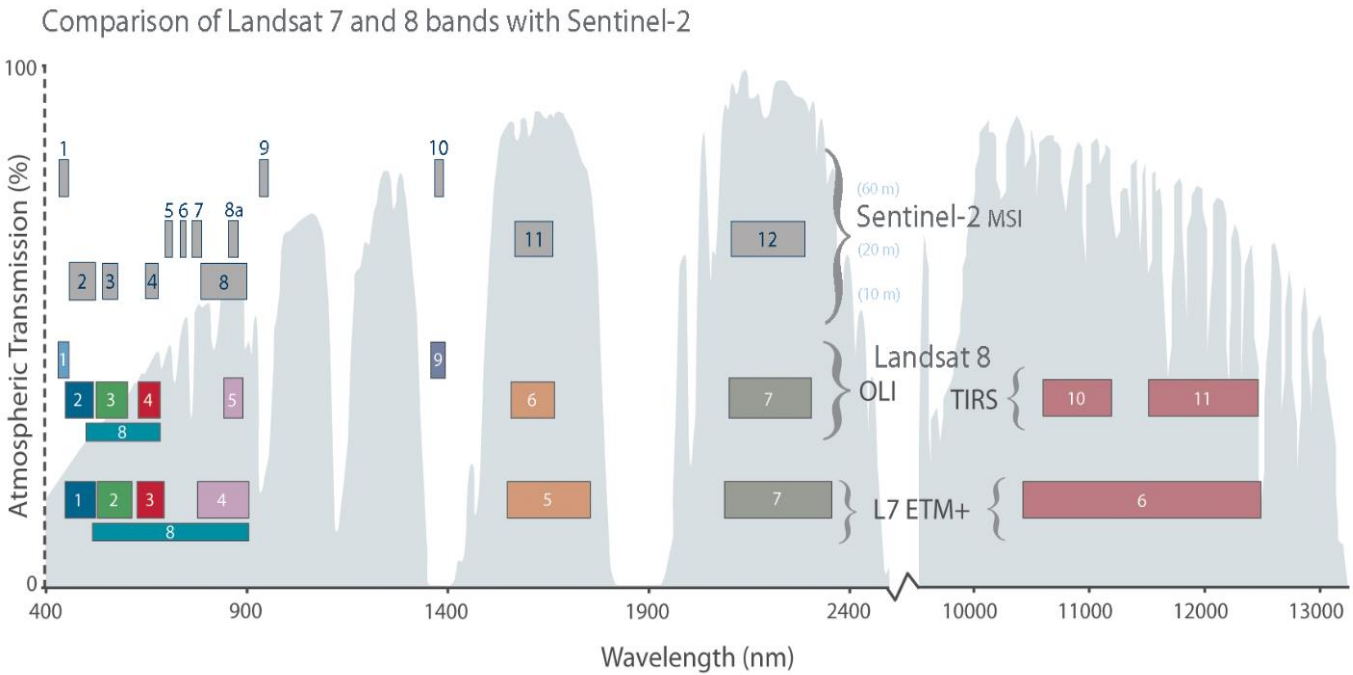
* Within the visible spectrum
**100-meter resolution data interpolated to 30 meters

Sentinel 2a Overview

- Launched June 23, 2015
- 10 day repeat coverage (5 day with Sentinel 2b)
- 3% absolute radiometric uncertainty (goal)
- Sentinel 2b launched March 7, 2017
- Equatorial crossing time: 10:30am
- Field of view: 20.6^o, 290km

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Landsat 8 & Sentinel 2



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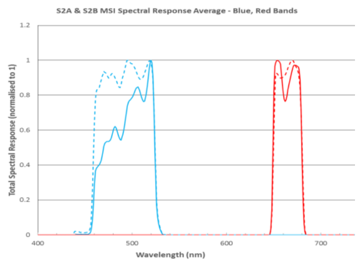
Calibration of Landsat 8 and sentinel 2

Refined APICS Model

- Existing APICS Model was developed with Landsat 7 spectral bands, there was no 'gain factor' specific for Coastal Aerosol band
- Refined APICS Model : generate gain factor cooperating the Coastal Aerosol band
  - using same Hyperion data that used for the APICS Model (5 dates)
  - correcting a function to calculate 'gain factor'
- Results of Refined APICS Model with
  - Landsat8- Collection1(BQA,SZA),
  - S2A (with RSR adj. in Blue band), and SZA over ROI
  - S2B ,SZA Center Scene



Improvement for All Satellites

Improvement for S2A Blue Band RSR Adj.

$$\rho_{Libya\ 4}(\lambda, SZA, VZA) = \frac{K(\lambda) * \rho_h(\lambda)}{[1 - (SZA - 30) * m_1(\lambda) - VZA(\lambda) * m_2(\lambda) - (VZA)^2 * m_3(\lambda)]}$$

where SZA, Solar Zenith Angle, VZA, View Zenith Angle

K = scaling factor, to place the Hyperion spectra ρh(λ), on the MODIS-calibrated scale

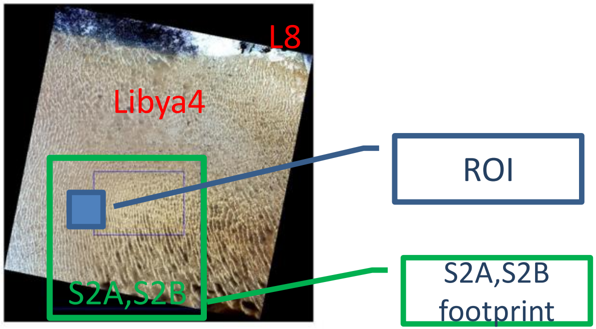
ρ_h = spectral content of the scene obtained using Hyperion, derived usingco-incident images (Hyperio&MODIS) Solar Zenith Angle < 35 and View Angle +/- 10 degrees (5 scenes)

m1 = The BRDF coefficients for solar zenith angle were derived using Terra MODIS and was scaled to 30 degrees solar zenith angle

m2,m3 = The BRDF coefficients for view zenith angle were derived using Hyperion measurements (± 15 deg)

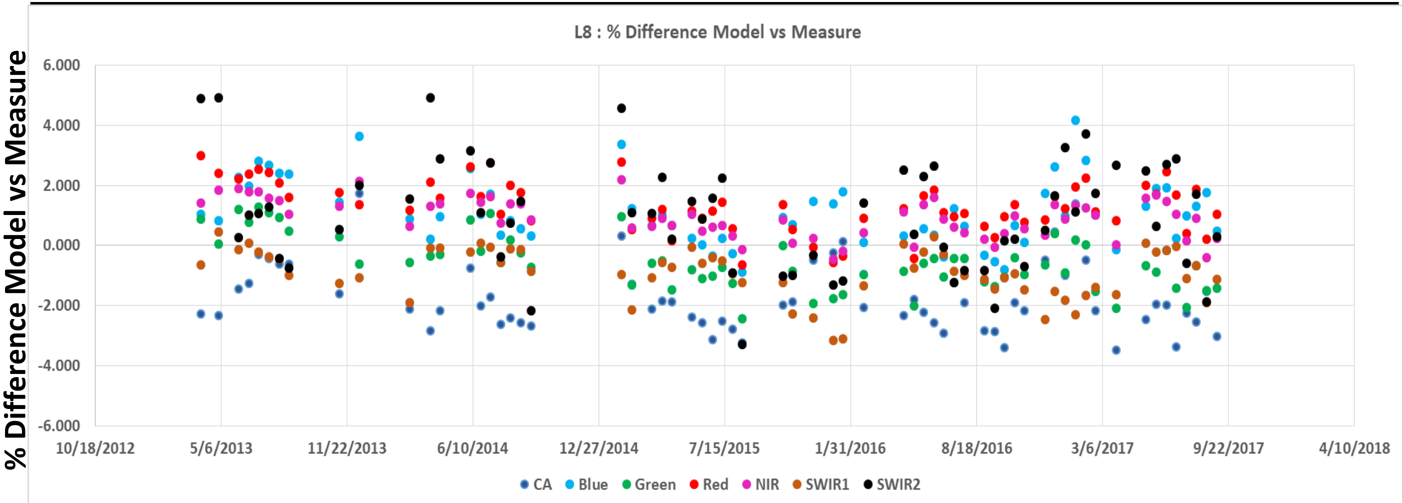
Data used for SDSU APICS Model

- **Libya4 PICS,**
- **Landsat 8 Collection1 data 2013- June 2017 (Path/Row :181/40)**
  - Band Quality Assessment and SZA Angle over ROI
- **S2A – With Blue band RSR adjustment, Aug 2015- Aug2017 : Tile 34RGS *with various data processing versions i.e. v.2.01 in Aug 2015 till v.2.05 at present***
  - SZA Angle over ROI
- **S2B – July 2017-September 2017 : Tile 34RGS**
  - SZA Angle – Center Scene



OLI-MEASURE VS SDSU ABSOLUTE CALIBRATION MODEL:

All available data from 2013 – Sep 2017 -: Landsat8 Collection1- BQA and Angle Information



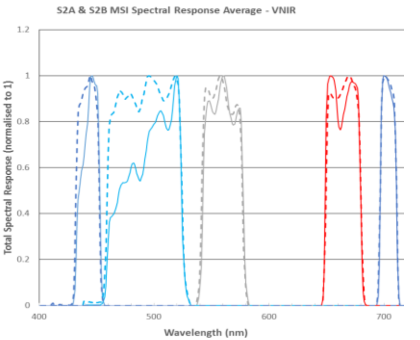
Landsat 8 -OLI	C/A	Blue	Green	Red	NIR	SWIR1	SWIR2
Avg, Measure	0.2287	0.2468	0.3368	0.4607	0.5836	0.6768	0.5985
Avg, Model	0.2328	0.2427	0.3402	0.4547	0.5783	0.6829	0.5926
Diff% Meas-Model	**-1.78%**	**1.68%**	**-0.99%**	**1.31%**	**0.91%**	**-0.91%**	**1.00%**
STD. of Residuals	**1.12%**	**1.08%**	**0.90%**	**0.85%**	**0.65%**	**0.82%**	**1.81%**

SDSU Refined APICS Model shows that the OLI absolute Calibration is generally well within 2%,For all spectral bands.

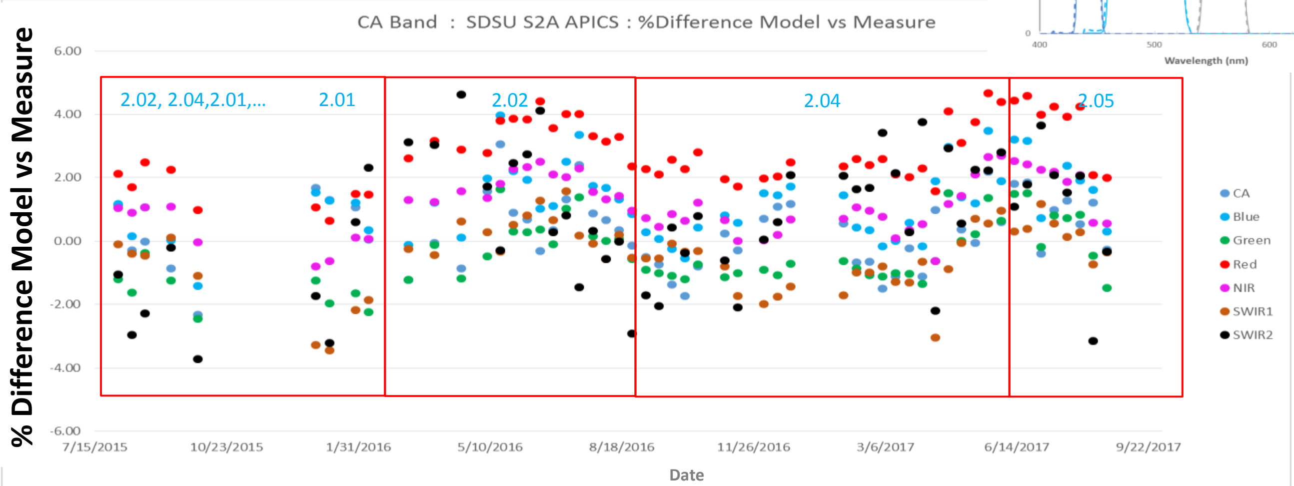
S2A MSI-measure vs SDSU Absolute Calibration Model:

All available data from Aug 2015 – Aug 2017

Various Data processing version since Aug 2015



Replace RSR Coastal Aerosol & Blue S2B for S2A



Sentinel 2A - MSI	C/A	Blue	Green	Red	NIR	SWIR1	SWIR2
Avg, Measure	0.2329	0.2547	0.3353	0.4753	0.5884	0.6823	0.5966
Avg, Model	0.2317	0.2517	0.3366	0.4623	0.5817	0.6854	0.5928
Diff% Meas-Model	**0.31%**	**1.22%**	**-0.42%**	**2.81%**	**1.14%**	**-0.47%**	**0.64%**
STD. of Residuals	**1.12%**	**1.11%**	**1.02%**	**1.03%**	**0.90%**	**1.09%**	**2.10%**

SDSU Refined APICS model shows that the S2A absolute Calibration is generally well within 1.5% ,except Red band within 2.8%

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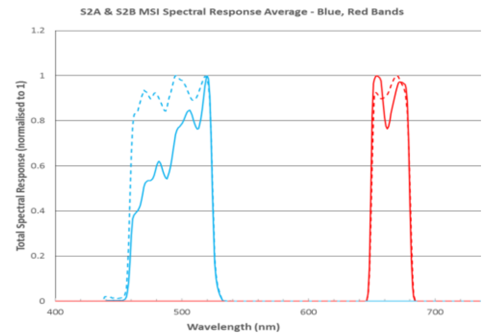
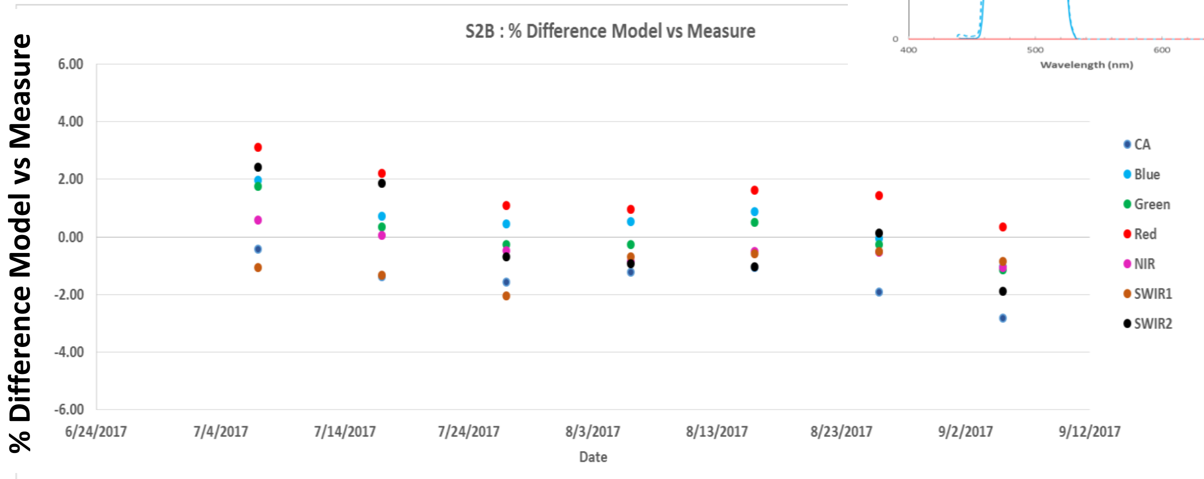
S2B MSI-measure vs SDSU Absolute Calibration Model:

All available data from July 2017 – Sep 2017



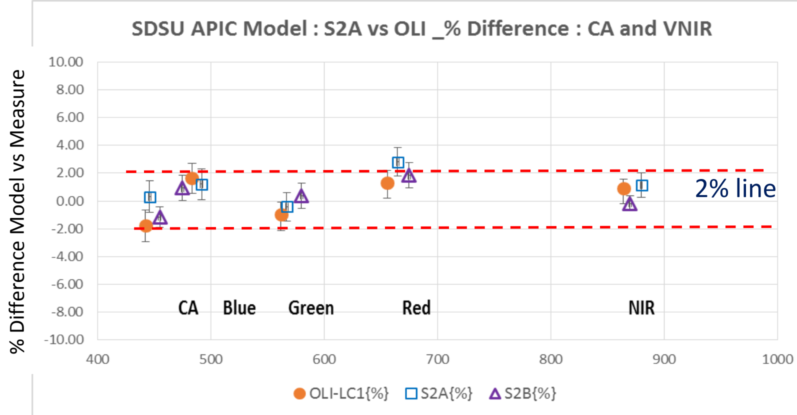


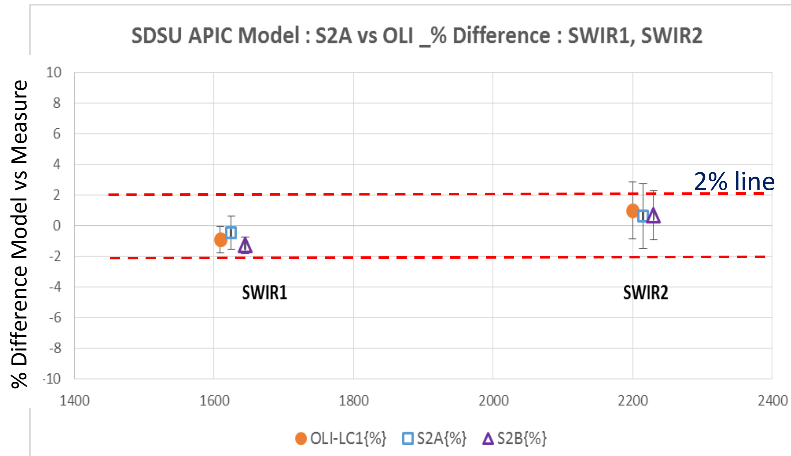
Sentinel 2B- MSI	C/A	Blue	Green	Red	NIR	SWIR1	SWIR2
Avg, Measure	0.2294	0.2548	0.3363	0.4760	0.5877	0.6828	0.6134
Avg, Model	0.2320	0.2524	0.3349	0.4673	0.5887	0.6916	0.6094
Diff% Meas-Model	**-1.15%**	**0.92%**	**0.39%**	**1.85%**	**-0.17%**	**-1.28%**	**0.66%**
STD. of Residuals	**0.74%**	**0.92%**	**0.90%**	**0.90%**	**0.56%**	**0.54%**	**1.60%**

SDSU Refined APICS model shows that the S2A absolute Calibration is generally well within 2% ,for all bands

SDSU Absolute Calibration Model results

- **OLI: all data available between March 2013 and Aug 2017**
  - OLI-LC1 absolute calibration is generally within 2%, for all bands
- **S2A: all data available between August 2015 and Aug 2017**
  - MSI-1 absolute calibration is generally within 2% except for Red band (2.8%)
- **S2B: all data available between July 2017 and Sep 2017**
  - MSI-2 absolute calibration is generally within 2% for all bands

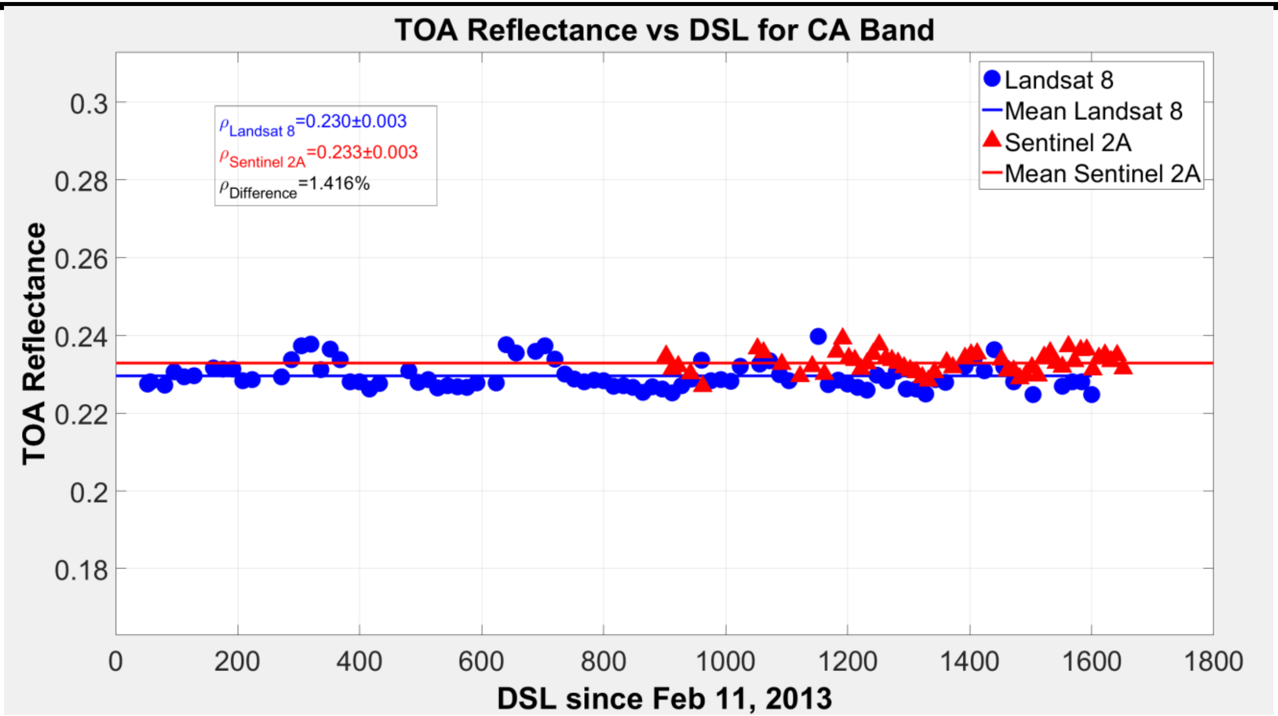




Landsat/sentinel data interoperability

- **TOA Reflectances**

Temporal Trend on Libya 4



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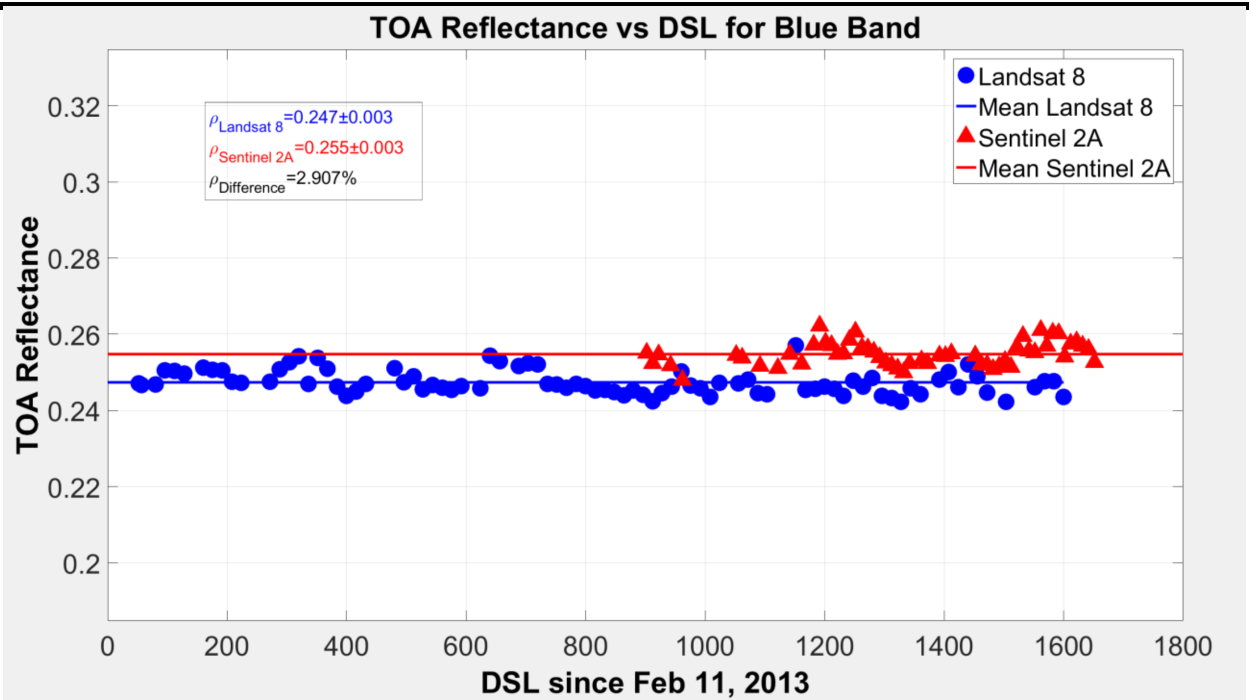
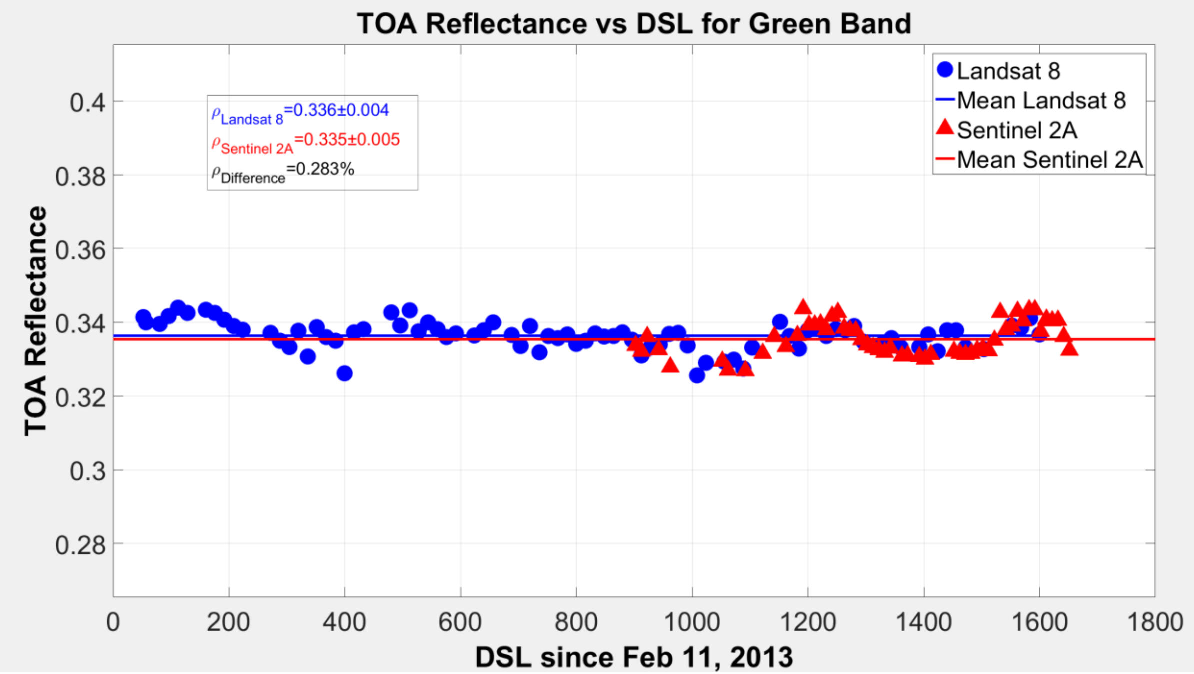
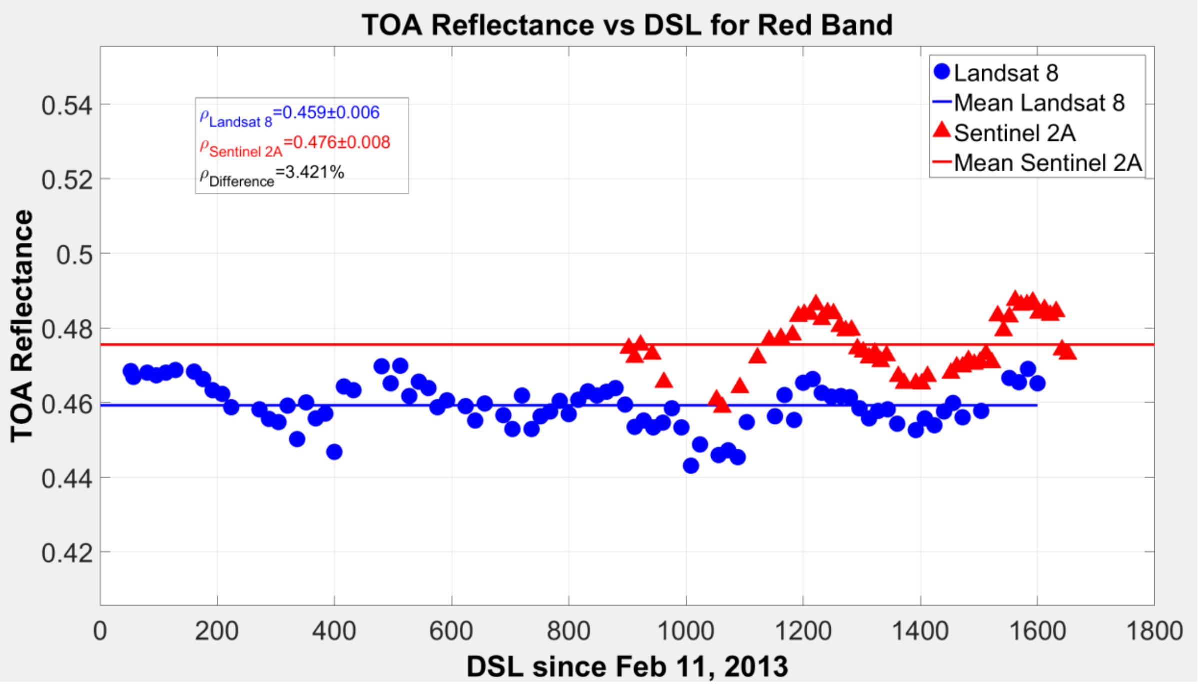
Temporal Trend on Libya 4



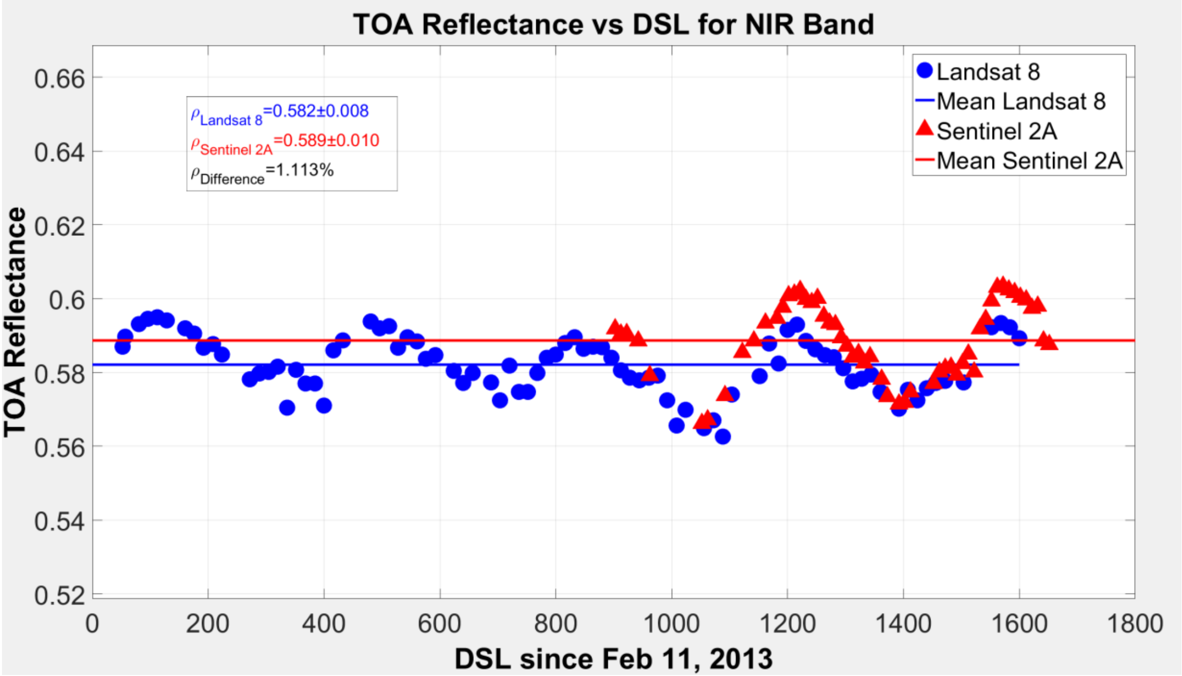
Temporal Trend on Libya 4



Temporal Trend on Libya 4



Temporal Trend on Libya 4



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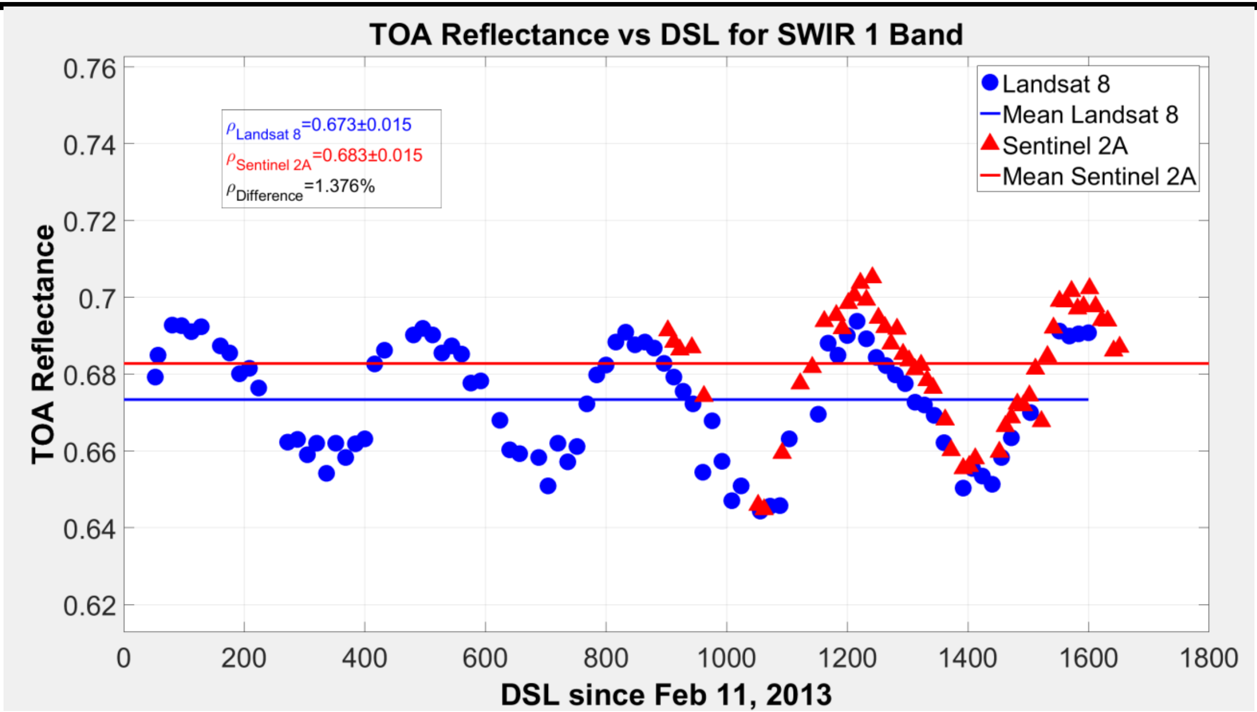
Temporal Trend on Libya 4



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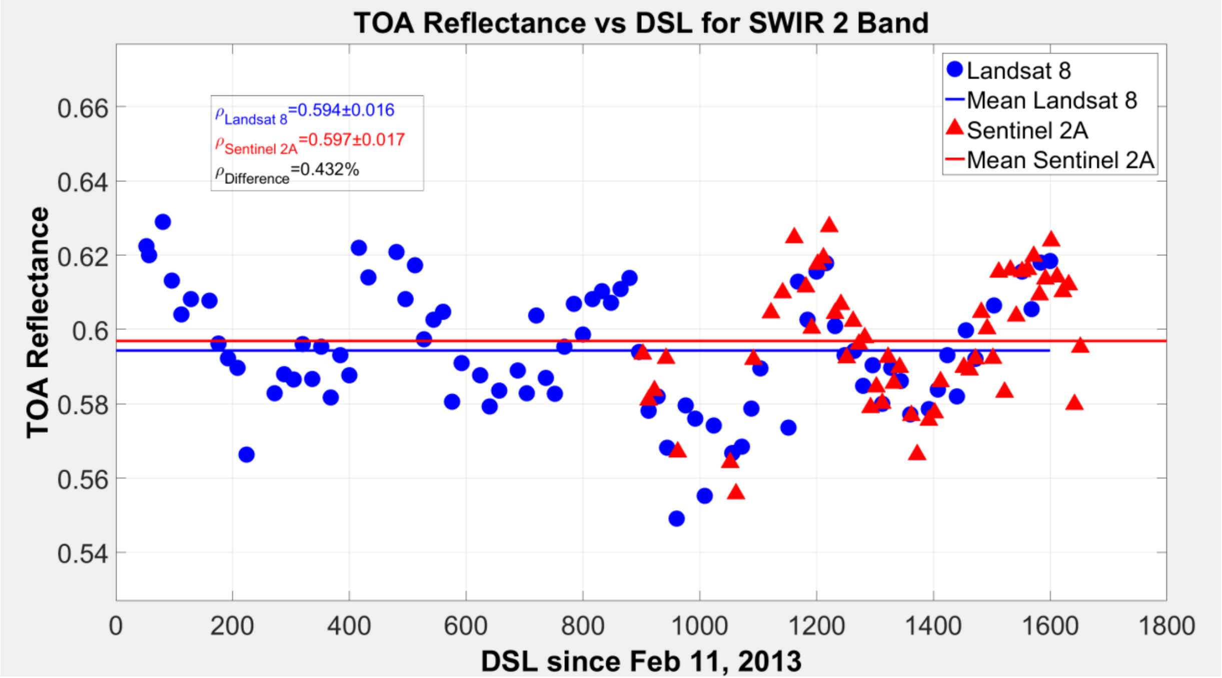

Landsat 8/Sentinel 2a Measurements of Libya 4

RAW TOA REFLECTANCE												
	L8	S2a	Abs. Diff.	% Diff.								
CA	0.230	0.233	0.003	1.4								
B	0.247	0.255	0.008	2.9								
G	0.336	0.335	0.001	0.3								
R	0.459	0.476	0.017	3.4								
NIR	0.582	0.589	0.007	1.1								
SWIR 1	0.673	0.683	0.010	1.4								
SWIR 2	0.594	0.597	0.003	0.4								

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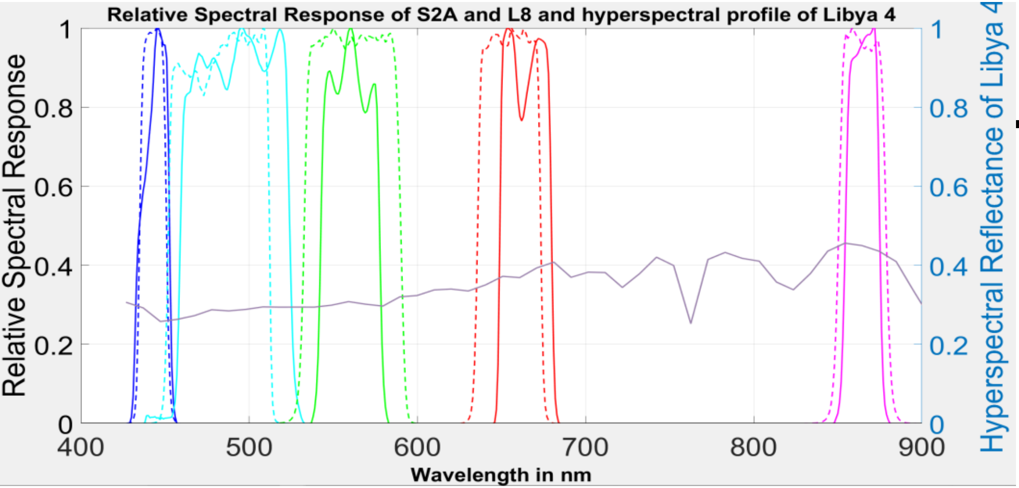
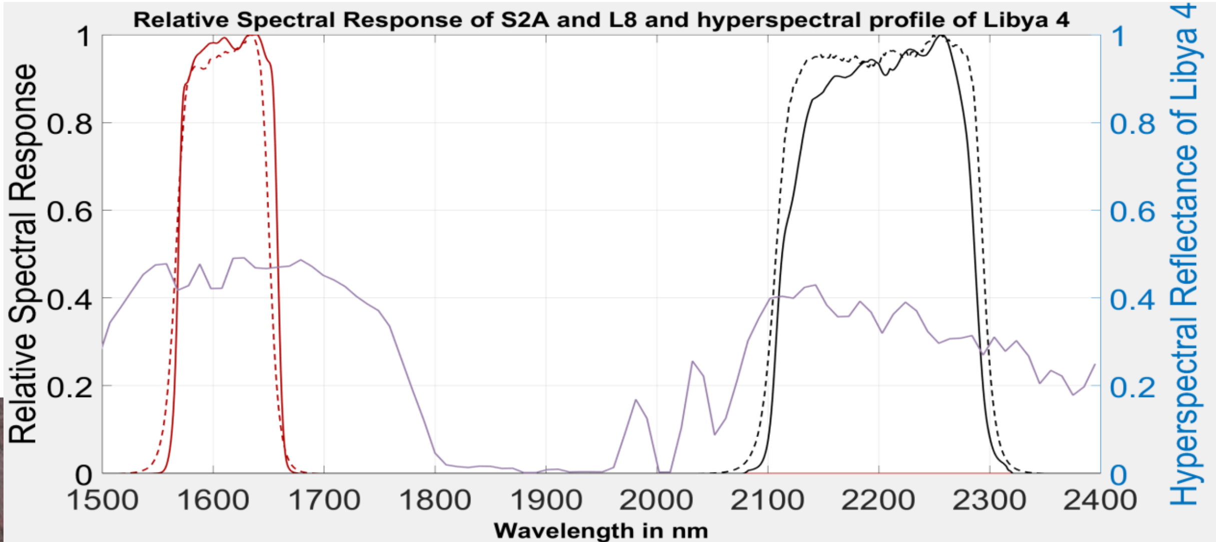
Landsat/sentinel data interoperability

- TOA Reflectances + SBAF Correction



Dotted Lines == Landsat 8

Solid Lines == Sentinel 2



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Spectral Band Adjustment Factor (SBAF)

The value of the reflectance in a specific spectral band of a sensor is calculated by integrating the SRF of the sensor with the hyperspectral reflectance profile, averaged by the respective SRF:

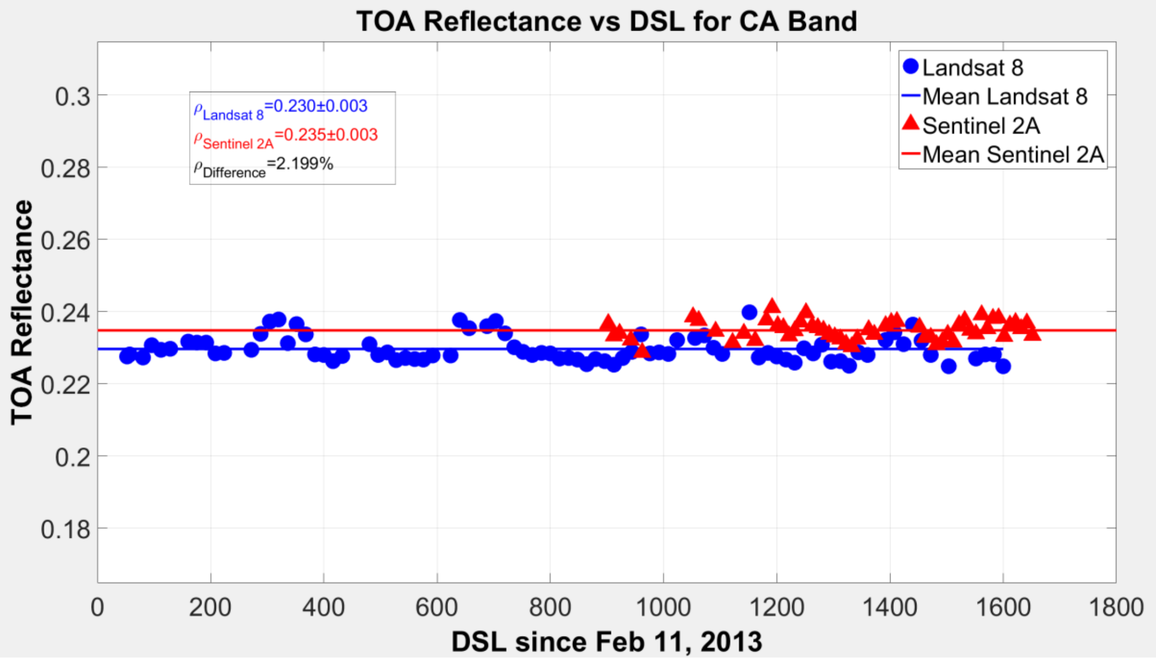
$$\rho_{band} = \frac{\int_0^\infty \rho_\lambda \cdot SRF_\lambda d\lambda}{\int_0^\infty SRF_\lambda d\lambda}$$

ρ_{band} is the averaged reflectance for each spectral band of the sensor [unitless];
ρ_λ is the hyperspectral reflectance incident [unitless]; and
SRF is the Spectral Response Function [unitless].

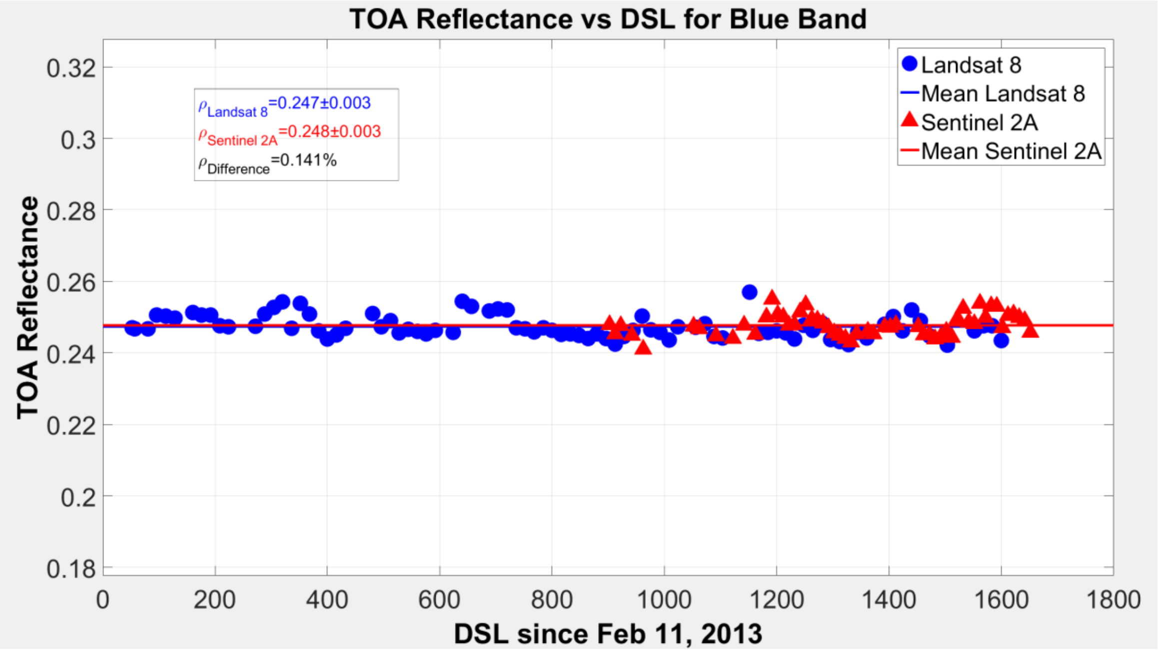
SBAF is the ratio of the reflectance of two sensors to compensate the differences in RSR of two sensors.

- $$SBAF = \frac{\frac{\int \rho_\lambda \cdot RSR_{\lambda(L8)} d\lambda}{\int RSR_{\lambda(L8)} d\lambda}}{\frac{\int \rho_\lambda \cdot RSR_{\lambda(S2)} d\lambda}{\int RSR_{\lambda(S2)} d\lambda}}$$

Temporal Trend on Libya 4 (After SBAF Correction)



Temporal Trend on Libya 4 (After SBAF Correction)



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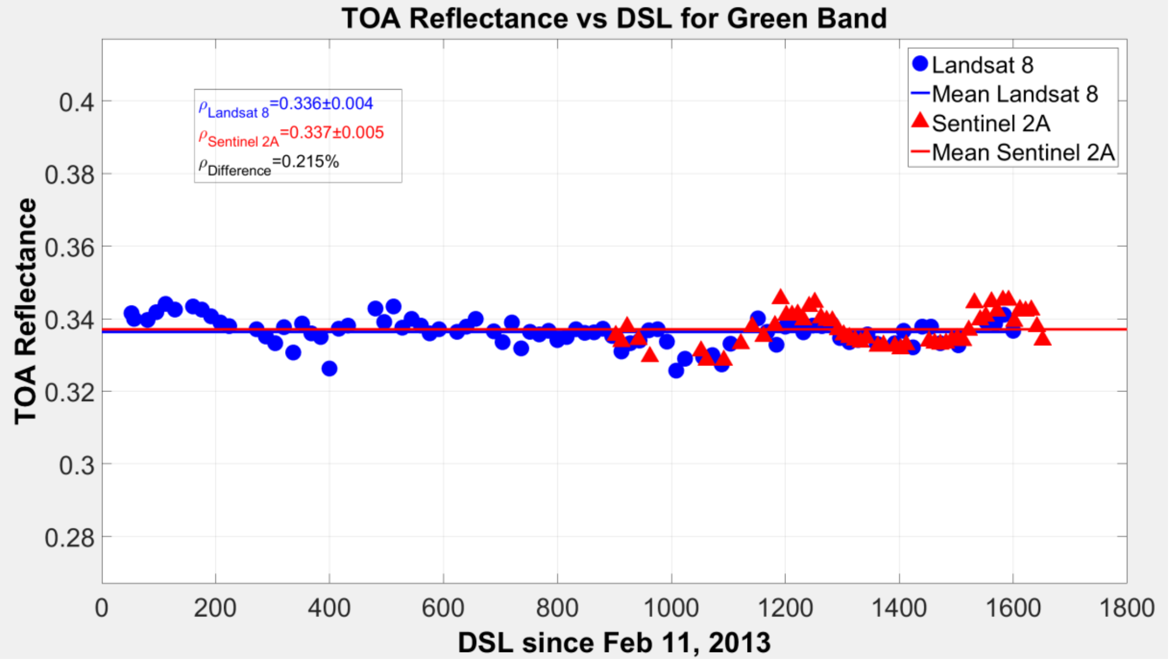
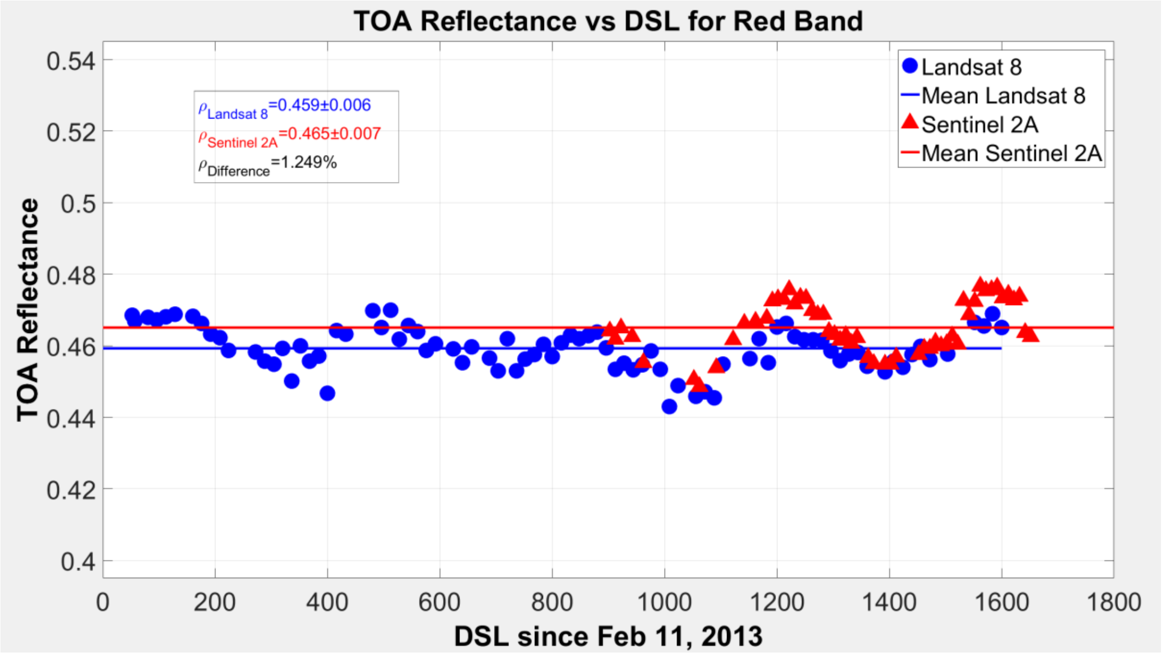
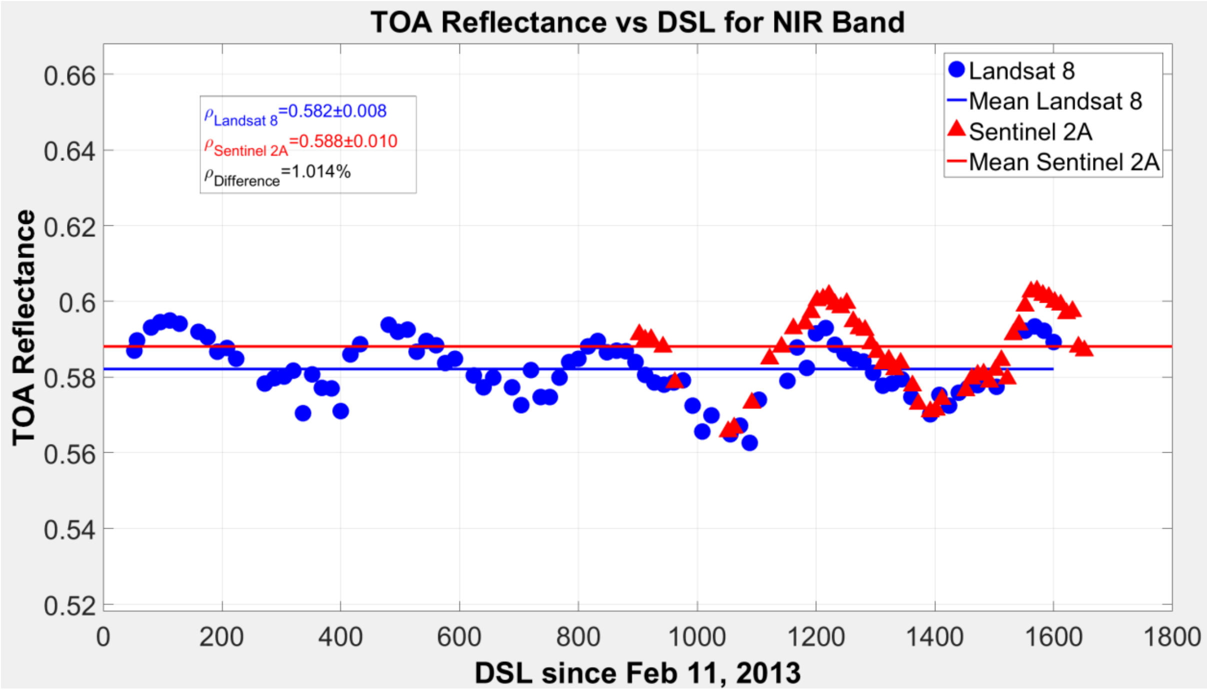
Temporal Trend on Libya 4 (After SBAF Correction)



Temporal Trend on Libya 4 (After SBAF Correction)



Temporal Trend on Libya 4 (After SBAF Correction)



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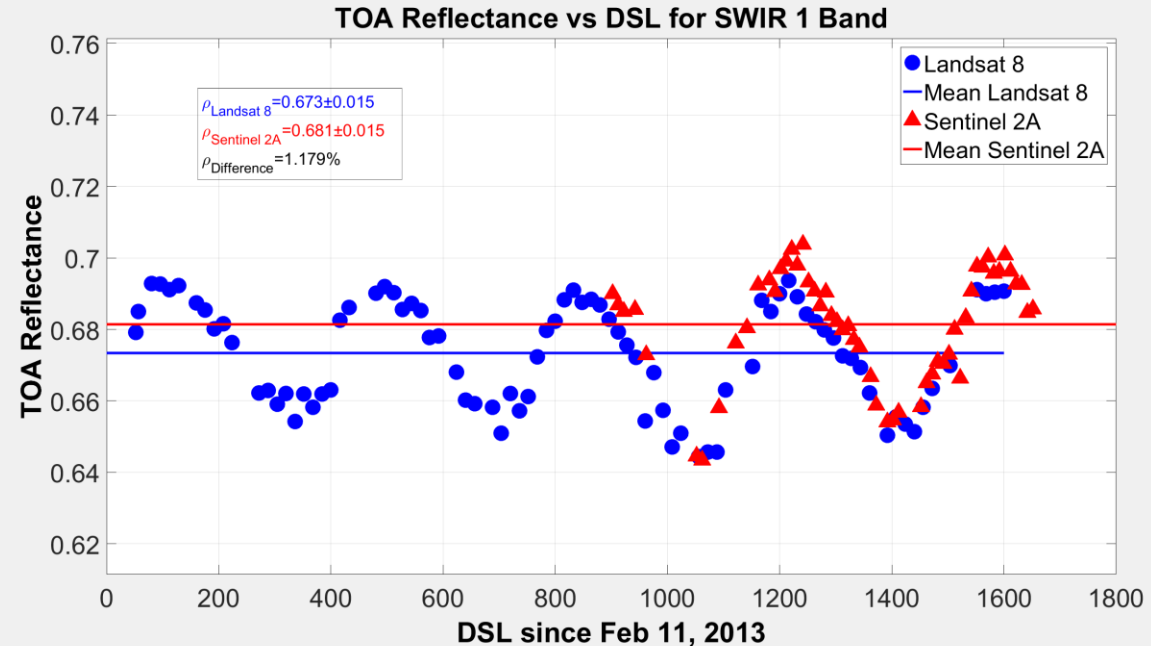
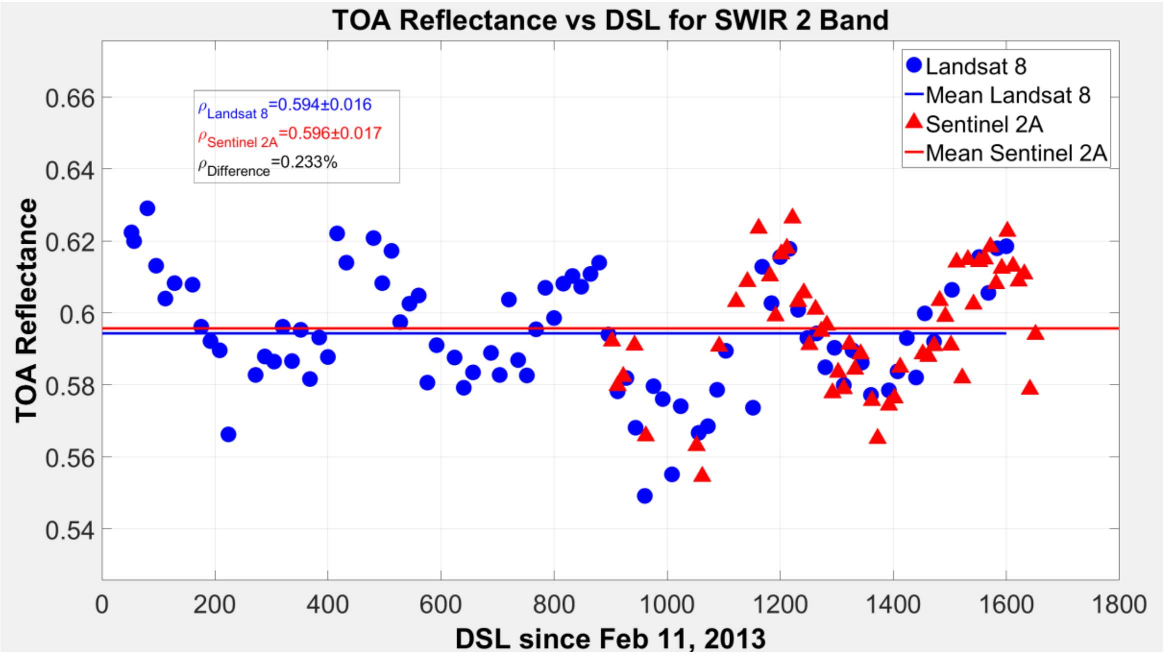
Temporal Trend on Libya 4 (After SBAF Correction)



Temporal Trend on Libya 4 (After SBAF Correction)



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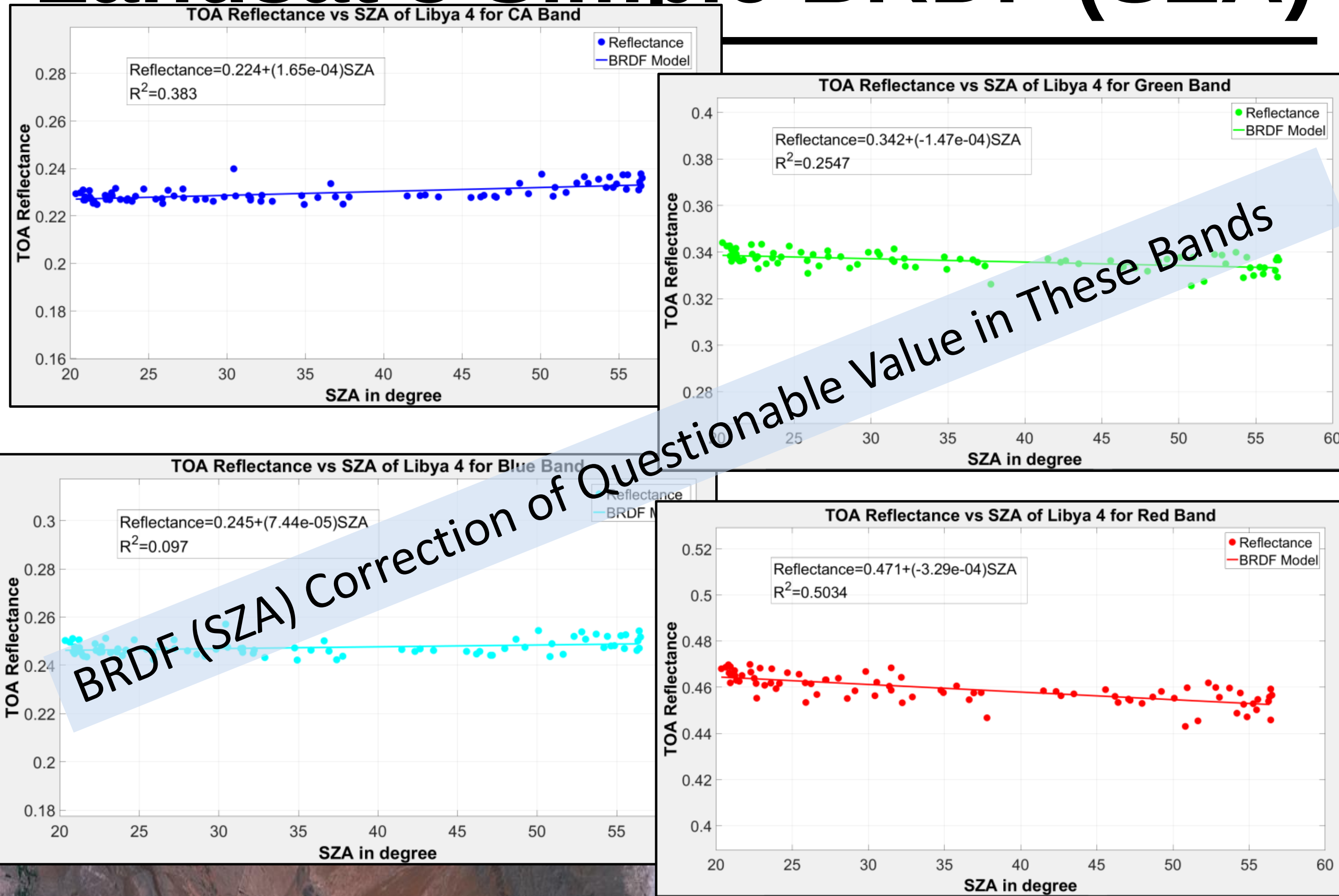
Landsat 8/Sentinel 2a Measurements of Libya 4

	RAW TOA REFLECTANCE				w/ SBAF Correction							
	L8	S2a	Abs. Diff.	% Diff.	L8	S2a	Abs. Diff.	% Diff.				
CA	0.230	0.233	0.003	1.4	0.230	0.235	0.005	2.2				
B	0.247	0.255	0.008	2.9	0.247	0.248	0.001	0.1				
G	0.336	0.335	0.001	0.3	0.336	0.337	0.001	0.2				
R	0.459	0.476	0.017	3.4	0.459	0.465	0.006	1.2				
NIR	0.582	0.589	0.007	1.1	0.582	0.588	0.006	1.0				
SWIR 1	0.673	0.683	0.010	1.4	0.673	0.681	0.008	1.2				
SWIR 2	0.594	0.597	0.003	0.4	0.594	0.596	0.002	0.2				

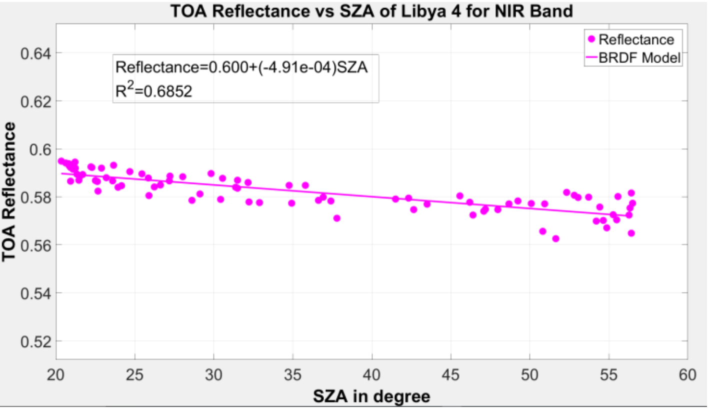
Landsat/sentinel data interoperability

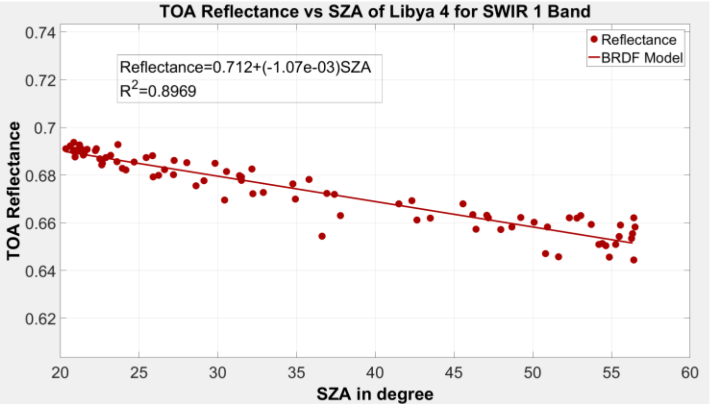
- TOA Reflectances + SBAF Correction+ SZA Correction

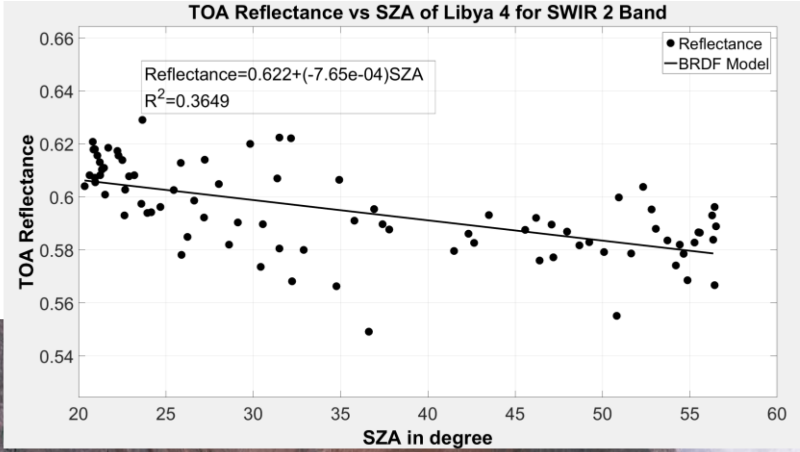
Landsat 8 Simple BRDF (SZA)



L8 Simple BRDF (SZA) Model







Statistically Significant Slopes in These Bands Suggest BRDF (SZA) correction would be useful

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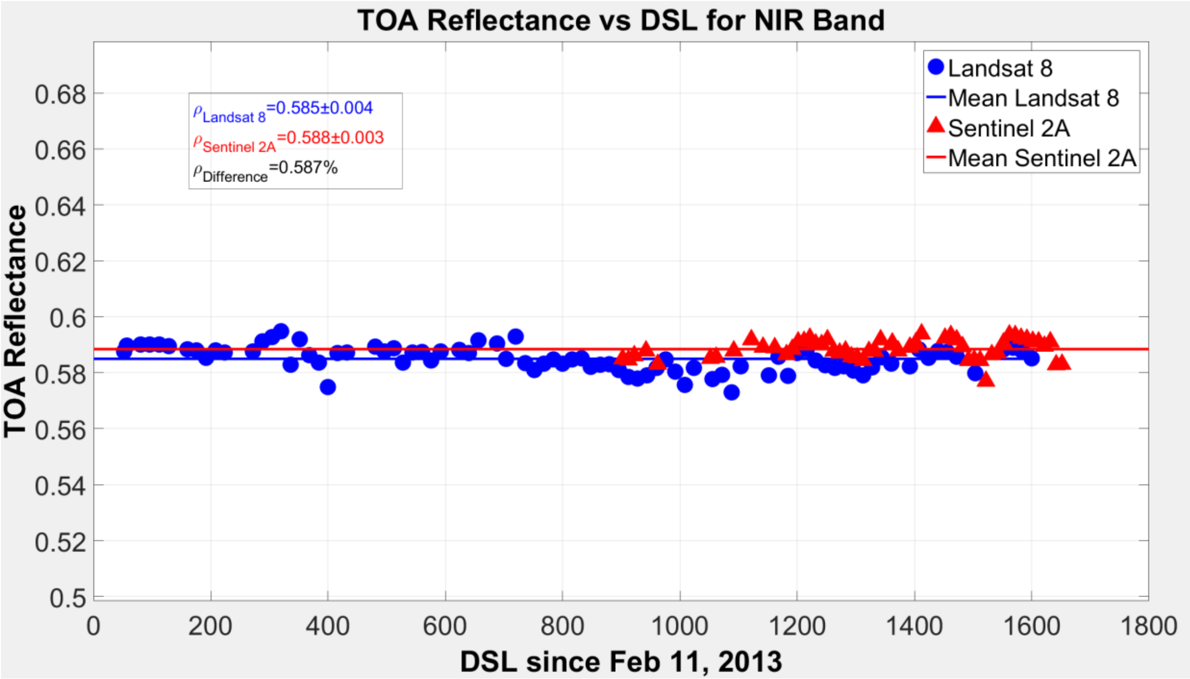
Reflectance comparison after BRDF+SBAF (Libya 4)



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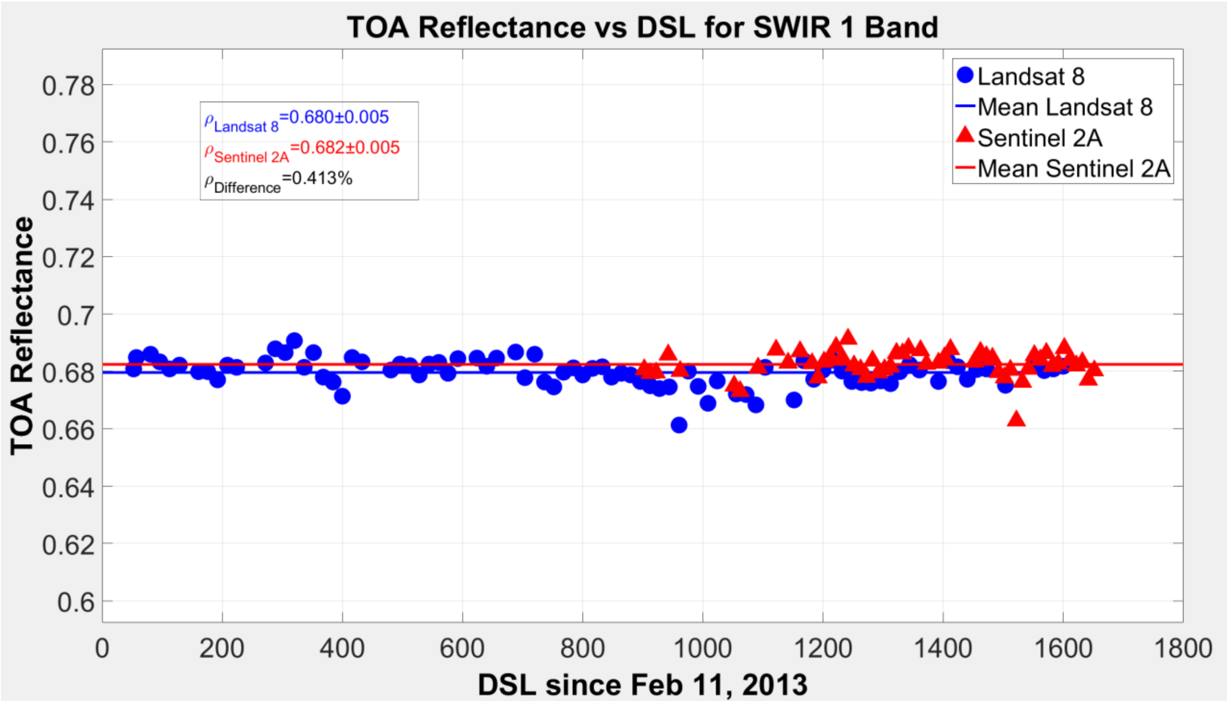
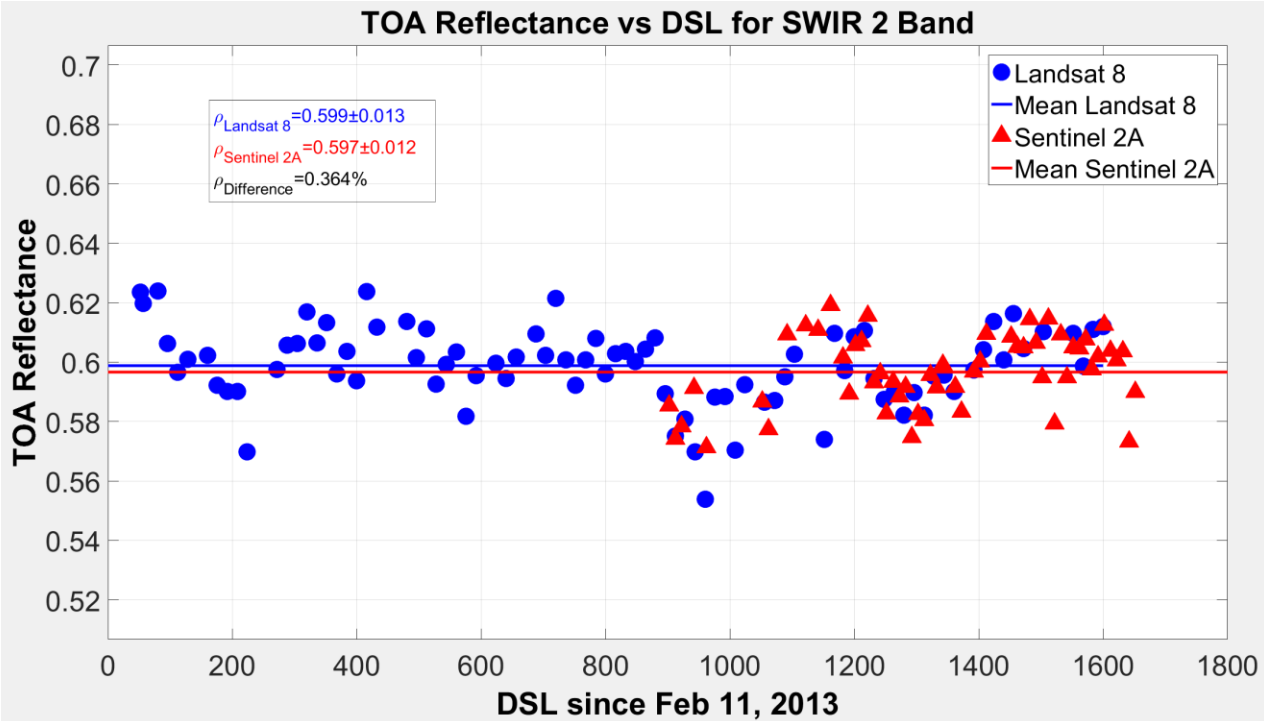
Reflectance comparison after BRDF+SBAF (Libya 4)



Reflectance comparison after BRDF+SBAF (Libya 4)



Landsat 8/Sentinel 2a Measurements of Libya 4

	RAW TOA REFLECTANCE				w/ SBAF Correction				w/ SBAF + SZA Correction			
	L8	S2a	Abs. Diff.	% Diff.	L8	S2a	Abs. Diff.	% Diff.	L8	S2a	Abs. Diff.	% Diff.
CA	0.230	0.233	0.003	1.4	0.230	0.235	0.005	2.2				
B	0.247	0.255	0.008	2.9	0.247	0.248	0.001	0.1				
G	0.336	0.335	0.001	0.3	0.336	0.337	0.001	0.2				
R	0.459	0.476	0.017	3.4	0.459	0.465	0.006	1.2				
NIR	0.582	0.589	0.007	1.1	0.582	0.588	0.006	1.0	0.585	0.588	0.003	0.5
SWIR 1	0.673	0.683	0.010	1.4	0.673	0.681	0.008	1.2	0.680	0.682	0.002	0.3
SWIR 2	0.594	0.597	0.003	0.4	0.594	0.596	0.002	0.2	0.599	0.597	0.002	0.3

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Conclusions

- **Well calibrated instruments ≠ Data Interoperability**
  - Landsat 8 and Sentinel 2 are both well calibrated instruments
  - Raw time series derived from both instruments are OK, but not without measurable offsets
    - More than one reflectance unit even in good scenarios
- **Spectral bandpass differences must be taken into account**
  - Biases can be reduced significantly, less than one reflectance unit in this case study
  - Requires knowledge of the thing you are measuring!
- **How can this issue be addressed?**
  - Suggests we need to consider the entire imaging chain from instrument design, instrument/data calibration, and atmospheric compensation to obtain consistent surface reflectance data products
  - For extended consideration of this topic consider attending…

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Thank You!

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